Industry Report: Digital Sorting Equipment for Nuts

Nut processors around the world work hard to produce various products (shelled or unshelled) that are free of foreign material (FM), extraneous vegetative matter (EVM) or Out-of-Specification (OOS) nuts to increase the value of their product. Various technologies and methodologies are applied at various steps in the processing line to further increase this value. Clean nuts are separated into distinct grades based on color, size and shape. These quality objectives are easily achieved with today's sophisticated range of digital sorting systems, enabling the ability to detect defects not visible by the human eye.

Specialized digital sorters have recently been developed to improve FM, EVM or OOS removal, enhance shape sorting, remove nuts showing signs of mold or aflatoxins, and more. These advances help processors achieve the highest quality while safeguarding yield through reduced false rejects, rework, and product degradation. With so many effective quality-improving tools now available, the challenge becomes identifying the optimal sorter configuration or combination of sorters to best achieve each processors' objectives.

In this white paper, we will explore the various types of sorting systems available to nut processors, including the latest state-of-the-art in color sorters, smart laser sorters, and new hyperspectral technology. The goal is to help processors of various nuts including walnuts, almonds, pistachios, peanuts, and other nuts, select the perfect sorting solution for their application.

The Ideal Sorting Solution

Most discussions about the ideal nut sorting solution begin with the capital budget. A processor that can afford only one system will be best served with a multipurpose sorter that can do everything required – remove FM and EVM, shells, fibers, and membrane, but also sort by color, size, and shape along with detecting signs of aflatoxins, if needed. If a sorter features two-way sorting (one infeed stream leading to one accept stream and one reject stream), the processor will run product through the same sorter multiple times, removing FM and EVM in the first pass, and grade product by color, size, and/

or shape during subsequent passes. This process involves some level of staged product buffering.

The multiple sort process with staged buffering can be avoided by implementing dual-pass sorting in which the sorter in feed is mechanically separated into two parts. One side performs the primary sort and the reject stream is looped back into the other side which performs a second sort. Alternatively, three-way sorting can be used, where the product is subject to two ejection criteria in a single pass. The advantage of three-way sorting is that the sorter can use its full sorting width in one sorting pass exposing the product to less handling. Therefore, dual-pass or multipurpose three-way sorting is usually ideal for processors who will invest in a single system. It is important to understand how much flexibility the process needs to maximize the yield of the sorter, so processors should consider things such as upgradability, flexibility and ability to retrofit when choosing a system. Modular systems that offer fast and easy change over can be an option.

For nut processors who can make a larger investment and prefer not to use buffering, the preferred solution is often installing multiple sorters in a sequence so only one pass is required. This approach, while initially more expensive, quickly improves profitability because it can double or triple production line throughput. It also enables better integration of various technologies, reduces labor costs and offers the benefit of multiple control points (avoiding single-point-of-failure issues) while achieving product quality objectives. In this scenario, the first sorter is typically focused on bulk FM and/or EVM removal and subsequent sorters focus on color, size, and/or shape while eliminating any residual FM.

Regardless of the number of sorters utilized, the best outcomes are achieved when mechanical graders, extraction systems, gravity tables, sieves, and other mechanical devices eliminate a large amount of FM and/or EVM prior to optical sorting. Thus, the ideal total solution is created from the optimal combination of traditional mechanical systems and digital sorters.

Laser and Laser/Camera Combo Sorters

Considered the "workhorse" in most nut processing plants, laser and laser/camera combination sorters make effective multipurpose sorting solutions. Depending on the needs of each application, today's most advanced laser sorters can be designed with up to five lasers operating at different wavelengths to detect and remove a wide variety of FM, EVM and OOS . The resolution and effectiveness of lasers over a wide range of FM, EVM

and OOS defects is an important contributor to global food safety. When combined with high resolution cameras for superior shape, size and color determination, the result is a high quality product.

Laser sorters inspect the distinctive structural properties of each object to reliably identify and remove FM such as plastics, glass, and stones, and EVM such as shells, sticks, and membrane, even when the material contains the same color as good product. A laser sorter is also capable of achieving color sorting, although advanced color cameras provide a more precise detection of very subtle distinctions in color shades.

If the sorter is equipped with a combination of lasers and advanced color cameras, fewer lasers can be considered as color cameras take over the color grading functionality from the lasers to enable a richer color grade contrast through millions of color differences to separate darker-colored nuts from lighter-colored nuts. With the appropriate software and algorithms, laser/camera sorters can also sort by shape, if needed.
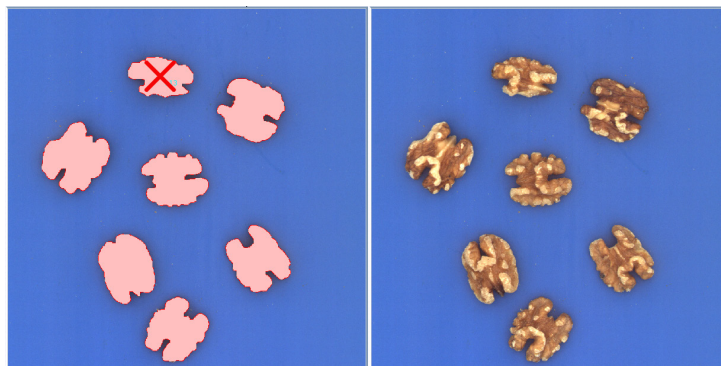
Shape Sorting

For nuts such as walnuts, shape sorting is an extremely important capability because halves with no broken shoulders sell for the highest price. In almonds, broken tip elimination can be a benefit. Very small pieces can easily be separated from large pieces via mechanical size grading, but shape sorting is needed to automate the separation of halves with broken shoulders from intact halves to produce the highest value product.

Advanced shape sorting can be accomplished with monochromatic or color cameras, coupled with powerful software algorithms. A camera-only sorter can be dedicated to shape sorting or a laser/camera combination sorter can achieve shape sorting in addition to FM, EVM and color sorting. The nut processor's capital budget, available floor space, and product quality objectives help drive the decision. An important factor in addressing state-of-the-art issues is to select sorters that avoid shade effects while creating the shape images and maximize contrast.

Three-Way Sorting

While most sorting challenges can be achieved through two-way sorting (one accept stream and one reject stream), it may be beneficial to consider sorters with two ejector systems and three outfeed streams to achieve three-way sorting. Most processors make the decision to minimize product handling to safeguard product quality and avoid the risk of damage, as every manipulation exposes the product to damage. When a multipurpose laser/camera combination sorter is equipped with three-way sorting, higher quality is achieved in a single pass. Generally, three-way sorting separates the incoming stream into a FM and EVM reject stream, a lower grade product stream and a premium product

stream. If the incoming defect load is high, the lower grade product stream may also be a rework stream that is resorted via a return loop back to the sorter infeed, buffered and sorted later, or fed to another sorter.

Compared to running product through a two-way sorter multiple times, a three-way sorter achieves similar results while cutting the number of passes in half, which doubles throughput, reduces labor, and minimizes product degradation. Compared to leveraging two-way sorters in tandem, a single three-way sorter can achieve similar results while reducing capital equipment requirements.
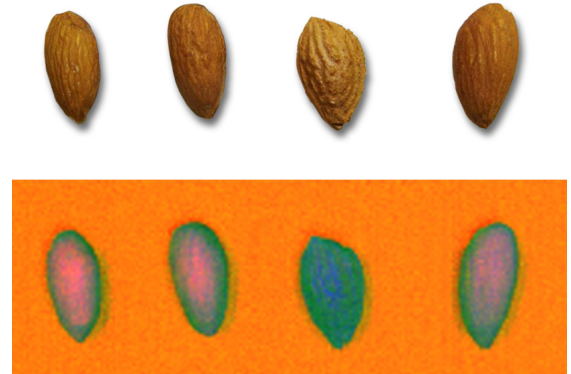
Aflatoxin Detection

Peanut processors are highly concerned with controlling the level of aflatoxins, however, other nut processors are increasingly looking to detect and reduce this harmful mycotoxin as legislative initiatives are heating up the debate about health risks. While today's sorting technologies cannot remove all aflatoxins, some are very effective in significantly reducing levels to make infected batches saleable/consumer grade.

Currently, the most successful aflatoxin sorters are laser-based that combine light information from the visible spectrum wavelength effectively with light information from the non-visible ultraviolet (UV) wavelength in combination with powerful software and highly specialized algorithms. These laser sorters detect BGY-fluorescence properties, which occur when the kojic acid that is often present with aflatoxins, reacts with the peroxidase which is omnipresent in most vegetative matter. By rejecting nuts with kojic acid, aflatoxin levels are reduced. By combining the aflatoxin option with multipurpose laser sorters, a powerful detection capability is created to remove the infected product along with FM and/or EVM.

Hyperspectral Imaging

The newest sorting technology to be commercialized for nut processing uses hyperspectral imaging rather than lasers or traditional cameras. Hyperspectral imaging systems divide light into hundreds of narrow bands over a continuous range of wavelengths that cover a vast portion of the electromagnetic spectrum. Hyperspectral cameras collect hundreds of data points at the same time as compared to the three data points of an RGB camera, or the single data point for each laser sensor. Advanced hyperspectral systems convert the data to create unique biological fingerprints for each object to create a powerful sorting experience. Essentially it enables detection capabilities based on chemical composition which is, to some extent, uncharted territory. The challenges of the technology are the speed required to process the enormous amount of data and the resolution of the images or the size of the defects that can be detected. Currently this technology is used on specialized sorters where it achieves unparalleled performance removing FM and EVM, even under high incoming defect loads.

The effectiveness of chute-fed hyperspectral sorters is field-proven to maximize the removal of shells, membranes, husks, hulls, and other FM or EVM from walnuts, pecans, almonds, pistachios, peanuts and other nuts. The technology increases FM and/or EVM removal, often achieving >99.5 percent efficiency with very low false reject rates.

For nut processors that can afford multiple sorters, a sorter based on hyperspectral technology focused on removing FM is often the first sorting step, followed by a high-end laser/camera sorter. It is also perfectly suited for a dedicated rework line that receives material rejected by mechanical equipment and other sorters to be reclaimed because it can handle high defect loads effectively while combining simple operational skills.

Reverse Sorting

Reverse sorting is a software-driven capability included on select laser, laser/camera, and hyperspectral technology-based sorters that enables the user to quickly switch the definitions of what is accepted and what is rejected. It is ideal for rework and when incoming defect loads are higher than 50 percent. Reverse sorting also allows processors to extract the remaining amount of good product from hash. Typically, sorters are programmed to reject FM and/or EVM but when running in reverse-sort mode, they are programmed to target good product. This approach uses less compressed air and, more importantly, it improves the results with a cleaner end-product when defect loads are high.

Many sorter suppliers claim a reverse sort capability but oftentimes, the adjustment requires a labor intensive recalibration, which may take more time than it is worth. On

select sorters, the switch from a forward sort to a reverse sort is achieved in seconds via the touchscreen control panel, with no recalibration or mechanical adjustments required.

X-ray for Embedded Defects

Not as common as camera and lasers, x-ray technology can also be used for sorting applications. While color, laser or hyperspectral technology based sorters focus today on surface related defects, x-ray has the capability to look inside the product by focusing on density properties. The application in the nut industry pivots around FM such as metals, glass and stones as they have a higher density compared to nuts. X-ray detection is typically found at the end of a processing line as the last quality check to remove any remaining FM. To ensure all FM is removed, some systems employ a push-rod ejection system that either opens a gate or pushes a scraper to remove the FM along with quite a significant amount of good product. Air ejection is also used, but requires very aggressive duration settings to ensure all FM is removed at this final step.

Sorting Platforms

In addition to the various types of sensors (laser sensors, traditional cameras, and new hyperspectral based technologies) and the proprietary algorithms that process and analyze the data to make accept/reject decisions, nut sorters also differ in their mechanical embodiment. Waterfall, chute-fed, and belt-fed sorters are all capable of inspecting product in-air and are suitable for nuts with varying degrees of success.

Waterfall sorters inspect product in-air during the freefall. Chute-fed sorters stabilize product on the chute prior to in-air inspection. Belt sorters stabilize product on a belt, inspecting the product while on the belt from the top and then feed the product off the end of the belt for in-air rejection.

Waterfall Sorter

Chute-Fed Sorter
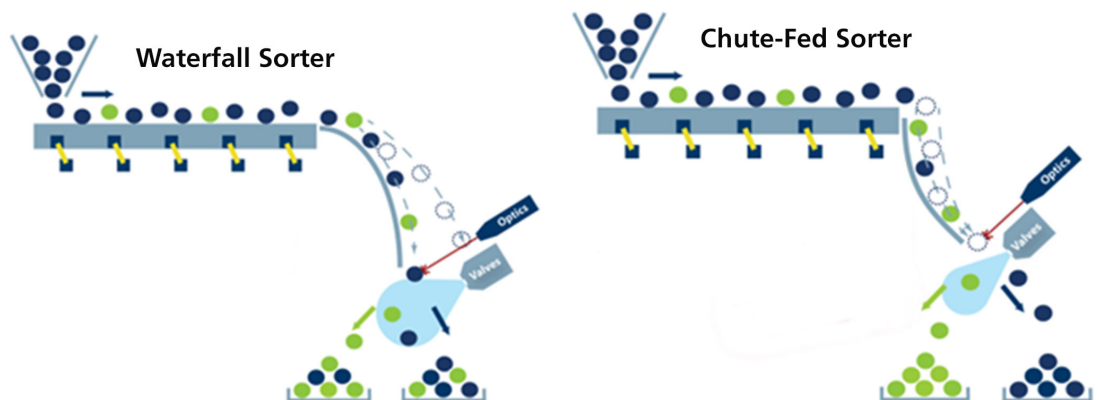
Stabilizing the product is critical to the sorter's efficiency. In general, stabilizing the product improves the predictability of the product trajectory while in the air through the inspection and ejection zones, which enables the sorter to better focus on objects to

identify small FM and/or EVM defects and improving the accuracy of the ejection system, both of which help maximize the sorter's yield and defect detection performance.

The major advantages of chute-fed sorters, compared to belt sorters, are the smaller footprint and the absence of moving parts, which contributes to low maintenance requirements. The major advantages of belt sorters are high throughput and the improved ability to achieve an effective three-way sort. Regardless of the platform, nut processors should look for sorters with low-impact infeed and discharge chutes that have been designed to minimize bounce and breakage for the gentlest product handling, so value isn't lost through product degradation.

Conclusion

With so many high performance sorting systems for nuts on the market and technology advancing at such a rapid pace, it can be difficult for processors to identify the ideal solution for their application.

Working with a supplier that offers the widest variety of nut sorting systems makes it easier to compare solutions and consider options. If the supplier offers mechanical grading systems in addition to digital sorting solutions, both aspects should be considered together to create the optimal combination. The supplier's nut processing expertise should not be undervalued – it contributes to the design of superior sorting systems, helps guide the processor's selection process, and can be tapped into long after installation and start-up in the processor's quest to continuously improve operations and final product quality.